Extreme precipitation and floods in the Iberian Peninsula and its socio-economic impacts

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AGU FALL MEETING

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INTRODUCTION

Extreme precipitation events in the Iberian Peninsula can induce floods and landslides that have often major socio-economic impacts.

The detailed reconstruction of past hydrogeomorphological disastrous events is very useful to improve our knowledge on the likelihood and preferred location of extreme events which will inevitably occur again and impinge considerable impacts on the territory.

We have analyzed in detail three extreme historical hydrogeomorphological events that occurred in Portugal, taking into account their wide socio-economic impacts (Fig. 1):

1 . December 1876 event (flash floods);

2. December 1909 event (floods and landslides);

3. November 1967 event (flash floods and urban flooding).

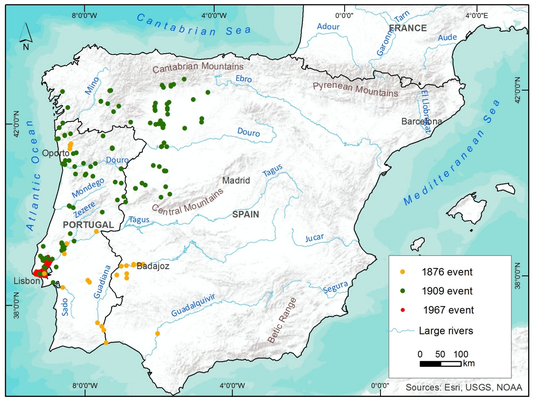

Fig. 1 - Hydrogeomorphological disaster cases

DATA AND METHODS

Historical data

The **DISASTER database** (Zêzere et al., 2014) gathered the basic information on past floods and landslides that caused social consequences in Portugal for the period 1865-2015. This database was built under the assumption that strong societal impacts of floods and landslides are sufficiently relevant to be reported by national and regional newspapers.

The entry criteria for the database are the following: any flood or landslide that, independently of the number of affected people, caused casualties, injuries, evacuated or homeless people.

In this work, historical newspapers from Spain were also used to collect data about socio- economic impacts of the hydrogeomorphological events.

Synoptic and rainfall data

Rainfall data was gathered from meteorological data digitized from several stations in Portugal and Spain.

Atmospheric circulation conditions were collected in the 20th Century Reanalysis data set from NOAA (Compo et al., 2011) and the atmospheric circulation during the months previous to these 3 events were assessed at the monthly, daily and sub-daily scales.

7-9 DECEMBER 1876 EVENT

Record breaking precipitation and floods

The first week of December 1876 (Trigo et al., 2014) was marked by extreme weather conditions that affected the SW sector of the Iberian Peninsula, leading to an all-time record flow in Tagus and Guadiana rivers. Several Portuguese and Spanish towns and villages located in the banks of both rivers suffered serious flood damage on 7 December 1876. These unusual floods were amplified by the preceding particularly autumn wet months, with October 1876 presenting extremely high precipitation anomalies for all western Iberia stations (Fig. 2).

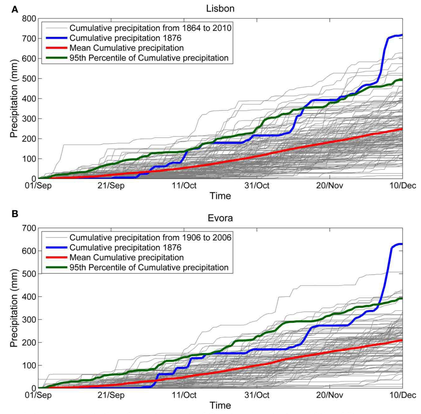

Fig. 2 - Cumulative precipitation from the 1st of September to the 10th of December using sation data. Each year of cumulative precipitation for (A) Lisbon (1864–2010) and (B) Evora (1906–2006) is represented in gray.

The first week of December 1876 was marked by extreme weather conditions that affected the south-western sector of the Iberian Peninsula, leading to an all-time record flow in two large international rivers. As a direct consequence, several Portuguese and Spanish towns and villages located in the banks of both rivers suffered serious flood damage on 7 December 1876.

Two digitized stations in Portugal (Lisbon and Évora), present a peak value on 5 December 1876. The values of precipitation registered between 28 November and 7 December were so remarkable that, the episode of 1876 still corresponds to the maximum average daily precipitation values for temporal scales between 2 and 10 days.

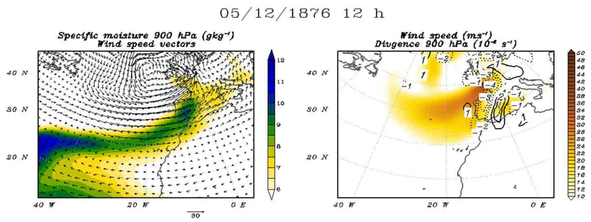

Fig. 3 - Wind speed and direction (arrows) and specific moisture (gkg^{-1}) color contours at 900hPa (left panels), wind speed intensity (colors,ms^{-1}) and divergence (solid) and convergence(dotted) contours at 900hPa (right panels) for selected days.

All months considered were characterized by a strong negative NAO index value, with November 1876 corresponding to the lowest NAO value on record since 1865. These events resulted from the continuous pouring of precipitation registered between 28 November and 7 December, due to the consecutive passage of Atlantic low-pressure systems fueled by the presence of an Atmospheric River with enhanced tropical moisture advection over central Atlantic Ocean (Fig. 3).

20-28 DECEMBER 1909 EVENT

Record of Disaster cases

According to the DISASTER database the 20–28 December 1909 event (Pereira et al., 2016) was the hydro-geomorphologic event with the highest number of flood and landslide cases that occurred in Portugal in the period 1865–2010 (Zêzere et al., 2014).

This event also caused important social impacts over the Spanish territory, especially in the Douro Basin, having triggered the highest floods in more than 100 years at the river's mouth in the city of Oporto.

The Iberian Peninsula was spatially affected by intense precipitation during this event along the SW–NE direction spanning from Lisbon, Santarém, Oporto, and Guarda (in Portugal), to Salamanca, Valladolid, Zamora, Orense, León, and Palencia (in Spain) (Fig.4).

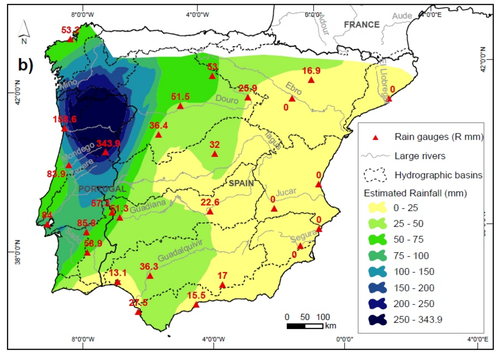

Fig. 4 - Co-kriging interpolation of the event cumulated precipitation in 20–28 December 1909.

In Iberia, 130 flood cases and 4 landslides cases were registered, causing 89 casualties (57 due to floods and 32 due to landslides) and a total of 3876 affected people, including fatalities, injured, missing, evacuated, and homeless people.

This event was associated with outstanding precipitation registered at Guarda (Portugal) on 22 December 1909 and unusual meteorological conditions characterized by the presence of a deep low-pressure system located over the NW Iberian with a stationary frontal system striking the western Iberian. The presence of an upper-level jet (250 hPa) and low-level jet (900 hPa) located SW–NE oriented towards Iberia along with upper-level divergence and lower-level convergence favoured large-scale precipitation.

Finally, this extreme event was clearly associated with the presence of an elongated **Atmospheric River, crossing the entire northern Atlantic Basin and providing a continuous supply of moisture that contributed to enhance precipitation** (Fig. 5).

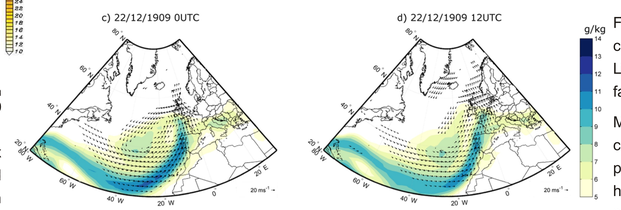

Fig. 5 - Wind vector (m s^{-1}) and specific humidity (shaded, g kg^{-1}) at 900 hPa level for the 22 December 1909 at (c) 00:00 UTC and (d) 12:00 UTC are also shown. Only wind vectors with wind speeds above 12.5ms^{-1} are shown.

25-26 NOVEMBER 1967 EVENT

Deadliest storm

The deadliest storm affecting Portugal since, at least, the early 19th century, took place on the 25- 26 November 1967 causing more than 500 fatalities (Trigo et al., 2016).

While most of the precipitation occurred around Lisbon area it also caused a SW-NE band of unusually high precipitation over the Portuguese territory (Fig. 6). Based on the sub-daily time series of a representative station, and its Intensity–Duration–Frequency curves, we have found that the exceptionality of this rainfall event is particularly linked to rainfall intensities ranging in duration from 4 to 9 h compatible with return periods of 100-years or more. This range of time scale which are similar to the estimated concentration time values of the hydrographic basins affected by the flash flood event.

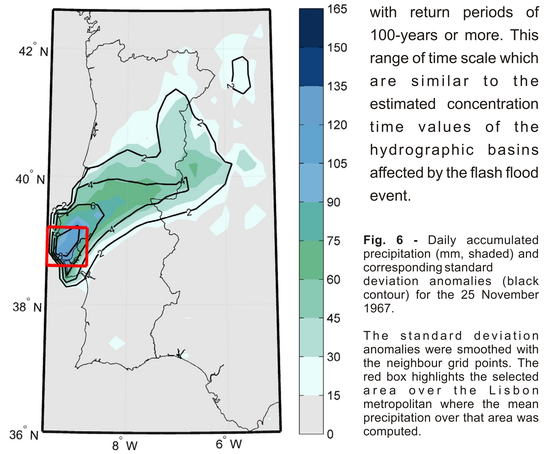

Fig. 6 - Daily accumulated precipitation (mm, shaded) and corresponding standard deviation anomalies (black contour) for the 25 November 1967.

The standard deviation anomalies were smoothed with the neighbour grid points. The red box highlights the selected area over the Lisbon metropolitan where the mean precipitation over that area was computed.

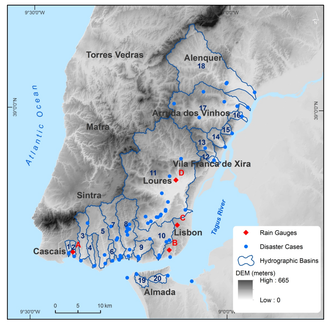

Fig. 7 - Location of the drainage basins affected by the November 1967 flood (blue numbers), the DISASTER cases (blue dots) and the rain gauges (red). Hydrographic Basins (blue polygons).

From a meteorological perspective, this episode was characterised by strong convection at the regional scale, fuelled by high availability of moisture over the Lisbon region associated with a low pressure system centered near Lisbon that favoured the convective instability.

Most victims were sleeping or were caught by surprise at home in the small river catchments around the main Lisbon metropolitan area (Fig. 7). The majority of people who died or who were severely affected by the flood lived in degraded housing conditions often raised in a clandestine way, occupying flood plains near the stream beds.

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